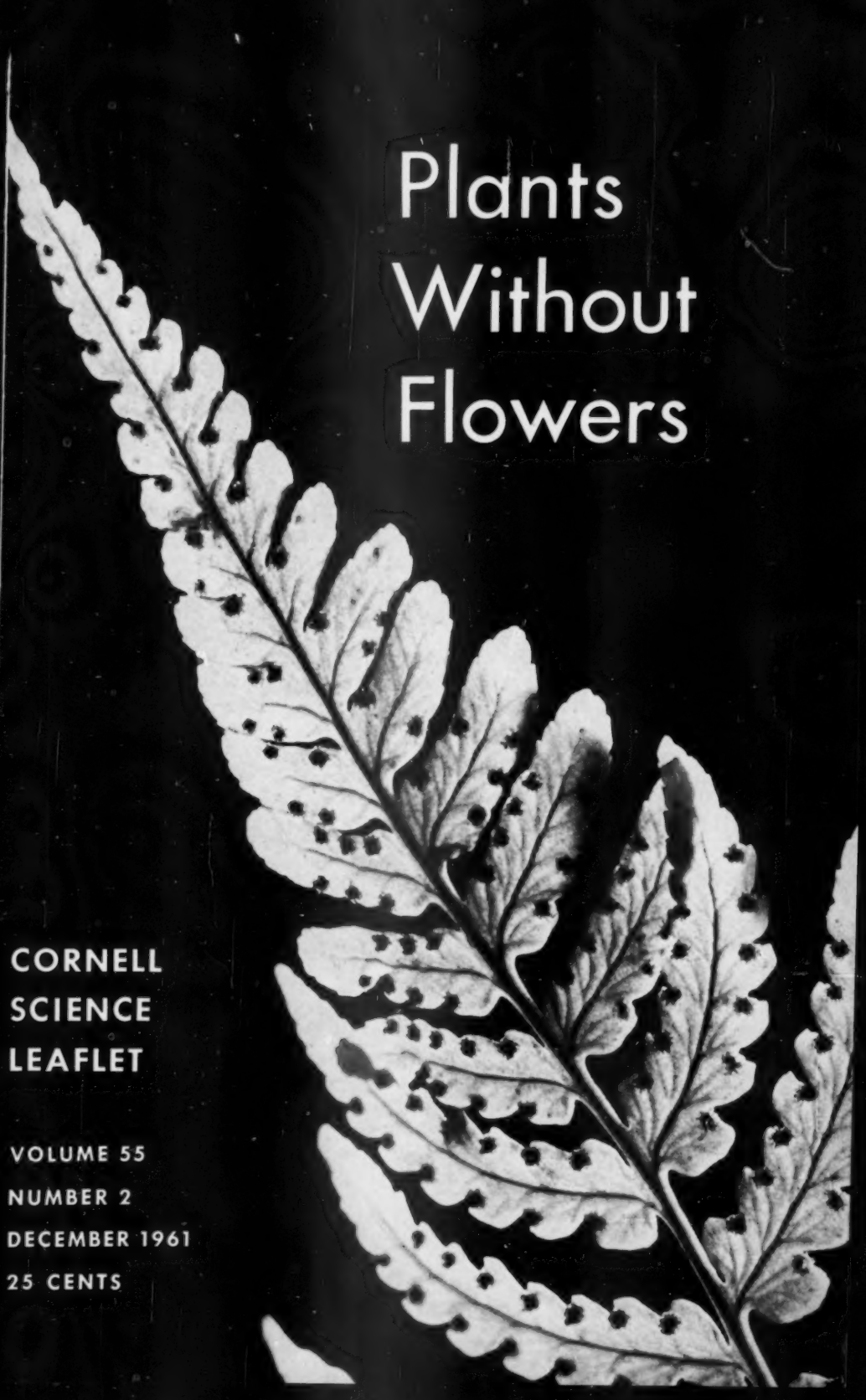
Plants Without Flowers



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Plants Without Flowers

VERNE N. ROCKCASTLE

When you ask a group of children, or even adults, to name a plant, most suggest a tree, grass, a flower, a weed, or a bush. All of these are seed plants, or plants with flowers. Although they are the most conspicuous land plants, and the ones that we depend upon most for food, for covering the soil, and for beautifying our homes, they are no more important to us than some plants that have no flowers and make no seeds.

Plants without flowers grow in almost all regions of the earth. Most of them are smaller than trees, or shrubs, or garden flowers. In fact, some are so small that you need a powerful microscope to see them.

Some flowerless plants help man; some hinder. Some are edible; some are poisonous to eat. Some are microscopic; some are huge. Some grow on land; others grow in the sea. Some make their own food; some are parasites on other plants. Some are so common that they become weeds; others are rare beauties. Some are commercially important and historically significant. All have a fascinating life story.

HOW CAN PLANTS REPRODUCE WITHOUT FLOWERS?

The flowers that are familiar to you, and which insects visit for nectar, are seed-makers. Most flowering plants such as peas, radishes, morning glories, lawn grass, and elm trees produce seeds after their flowers are pollinated and fertilization has occurred. Then a microscopic new plant is formed. The new plant grows a little, then usually stops growing and a hard protective cover forms around it and its food. It is now a seed — a tiny partly grown plant, with some food to help it resume growing when it is planted. SEEDS, the Leaflet for Spring, 1961, tells more about how this happens.

Some flowering plants not only produce seeds, but have developed other ways of spreading. Strawberries grow runners that make new plants; potatoes form tubers with buds called eyes that can make a new plant; quackgrass and poplar trees send out underground stems that push up now and then to form new plants.

Some kinds of flowerless plants also spread by sending out runners and underground stems. Some have

This Amanita mushroom may look beautiful, but it is deadly to humans who eat it. Its spore print is white.

special structures that are washed away by water to form new plants. Some grow new plants by breaking into bits, each bit becoming a new plant. Most, however, have tiny structures that act like seeds, but do not come from flowers.

Instead of seeds, many kinds of flowerless plants develop *spores* that are much simpler than seeds. Spores are one-celled structures that are small and light enough to be carried by the wind and water. Spores are so tiny that you can hardly see them. Magnified, they resemble pollen grains or dust. When conditions are favorable, spores germinate to form new plants just like the parent plants.

Spores are different from seeds in the following ways:

Spore

Usually one-celled
First cell of a new plant
Does not contain food supply
Formed by primitive plants
Almost no special attachments for travel

Seed

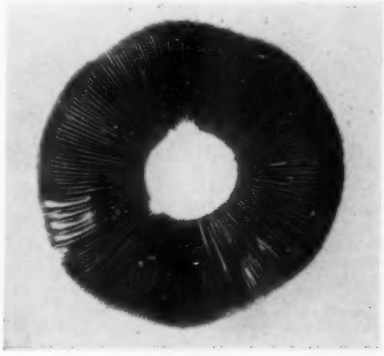
Many-celled
Partly developed new plant
Often contains supplementary food
Formed by more advanced plants
May have wings or silk to help travel

The special structures that help scatter seeds may be hooks (burdock); silky hairs (milkweed); or wings (maple). Spores are mostly tiny, round, and smooth. They depend upon their size and their tremendous numbers to insure scattering.

How Spores Develop

To see where spores come from, collect a gilled mushroom like the one shown on page 4. Break the cap from the stalk and place it, gills down, on a piece of white paper. Cover the cap with a dish and leave it undisturbed for a day. When you lift the dish and the cap, you may see a spore print left by thousands of spores that fell from between the gills. The dish helped keep the air from blowing them away.

Some spores are white and will not show up on white paper. Since your mushroom might have white spores, put a second cap on a piece



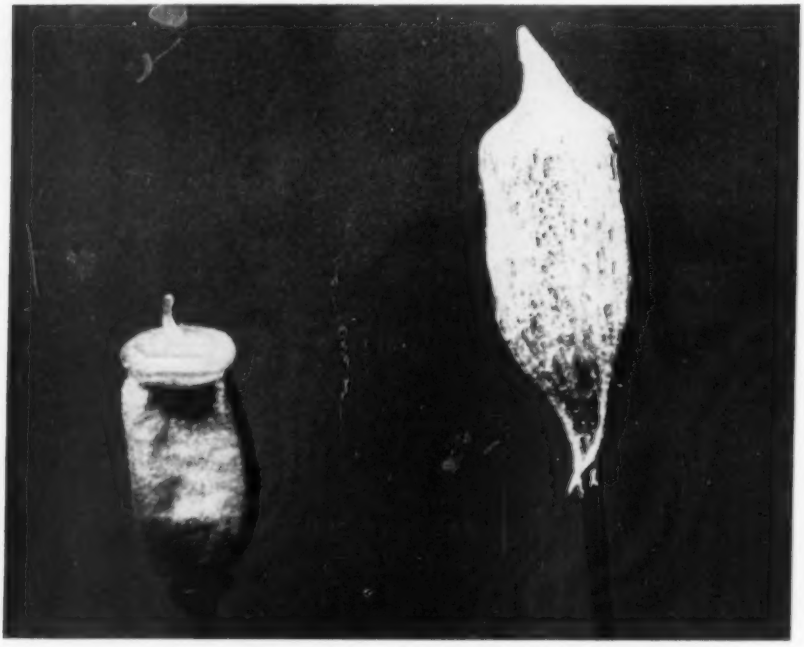
The spore print of the common field mushroom is brownish purple.

of dark paper. Then one of the spore prints should be visible.

Can you find other fungi that have pores instead of gills on their undersides? What kind of a spore print would a pore-bearing mushroom make?

In late summer and through the fall you often see a coarse, leafy moss known as hair-cap moss, or pigeon wheat, growing in thick mats along woodland borders. Sticking up from the mossy mat are slender stalks, each with a capsule the size of a rice grain at its tip. Examine these capsules carefully with a magnifier. Can you see that each has a pointed papery hat covering it? If you pick off a hat with tweezers or your fingernails, you may see a still smaller lid underneath.

Under this lid and projecting from the rim of the capsule are dozens of tiny teeth whose tips are connected. When the weather is wet, the teeth swell and close all the openings. In dry weather the teeth shrink and shrivel, and leave nu-



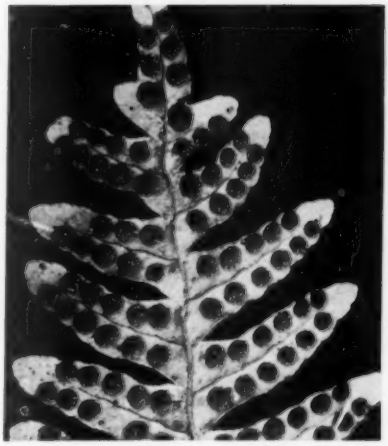
The ragged calyptra on the common hair cap moss at right is all that is left from the female reproductive structure. Under it is a second lid like that on the left. Under it are spores.

merous openings through which spores can shake free. Then the capsule is like a miniature pepper box, scattering spores to the breeze. Can you understand why it is better for the plant to scatter the spores in dry weather than in wet weather? When would spores travel farther?

Other mosses have capsules with different shapes, and with slightly different means of scattering their spores. Examine a number of different kinds in late summer or fall. If you examine them in the spring, you may be able to see the new growth of stalks and their slender, unripened capsules.

In most ferns, spores are formed in clusters of dot-like structures called *sori* (sow'-rye) or fruit dots on the underside of the fronds or leaves. Turn over a green fern frond and examine the underside. Can you see rows of dots, each a little larger than a pin head? Not all fronds of a species that produces these fruiting dots will show them; you may need to look at several before you find one with dots.

Each sorus or fruit dot is a cluster of several *sporangia*. Each sporangium is a thin-walled sac containing a number of spores. When the weather is dry, the sac breaks open and out spring the spores. The manner in which the sporangium breaks is amazing. There is a ring of cells around it, like a finger surrounding a ping-pong ball. This ring of cells curves back in dry weather,



Some of the largest fruiting dots (sori) can be found on the underside of the rock or Polypody fern.

splitting open the sporangium. After the ring has sprung back a certain distance, it snaps forward again, flinging spores far and wide. In wet weather it closes and waits for the next dry spell.

The sensitive fern bears its spores in a special frond that curls and becomes hard and brown in cold weather. You can see these *fertile* fronds projecting above the snow in winter. They bear little resemblance to the *sterile* fronds that have a more fern-like appearance, but which die quickly at the first frost. Inside the wrinkled, brown fertile stalks are the spores for a new generation of sensitive ferns. Other ferns have equally specialized places to make their spores.

In most of the club mosses, like the one on page 28, the spores are produced in slender cone-like structures at the top of the plant. In some woods in autumn, these spores are so numerous that a golden dust rises from mats of these plants when a person walks through them. In wet weather, few of the spores are scattered.

Bread mold is a flowerless plant that is not green and is very tiny compared with mosses and ferns. You can grow bread mold easily, despite the mold inhibitor that usually is added to the dough in bakeries. Put a slightly moistened slice of bread on a table top for a few hours, then enclose it in a jar or plastic bag and leave it in a warm, dark place. Look at it each day to see how the mold is progressing. Bread mold spores are formed in almost microscopic sporangia that stand like black knobs on white or colorless hairs. When lots of bread mold is present, the hairs make the bread look fuzzy. A day or two after the white fuzz appears, some of the sporangia can be seen. Examine them closely under a magnifier; each may contain as many as several dozen spores. These spores may drift about in the air for days, landing and then blowing away again until they come to rest on a surface where the moisture and temperature are right, and where there is plenty of food on which to grow.

In this mold growing on a pumpkin, the ripe sporangia are the dark dots; the unripe ones are still white.

When this clump of club mosses was distributed, it produced a thick cloud of yellowish spores.

As you examine flowerless plants of all kinds, you will see an amazing variation in the formation and scattering of spores. Some come from the surfaces of gills, some from pores,

some from capsules, and some from special sacs located at various places on the plant. Wherever they are formed, and whatever their number, their purpose is the same — to make new plants.

How Do Spores Make New Plants?

If spores that are spread by wind or water land in a place where the temperature and the moisture are right, they may germinate. Unlike seeds, which contain partly grown new plants, spores have not started their growth when they land. Most seeds store food to help the new plant grow until it can make its own food; spores have no such food supply.

When a spore begins to grow, it sends out a tiny thread of cells. If it is a liverwort or a fern spore, this thread soon becomes a tiny, flat, green plant; the thread is green if it is a moss spore, and whitish if it is a fungus. The plant that grows from a fern or moss spore is called a *thallus*. The thallus is a simple plant with no leaves or stem, and no means of making more spores. Instead, special structures with male and female parts grow from the thallus. In the male portion, sperms develop; in the female portion, an egg develops. When the sperms and the egg are mature, the sperms escape from the male part and swim in the moisture around the thallus. When one of them meets an egg and fertilizes it, the fertilized egg grows into a plant that can make spores.

In most ferns the thallus that grows from a spore is so small that you probably have never seen one. It is flat and no larger than your little fingernail. The male and female parts grow on its underside. When an egg is fertilized, it grows into a big leafy fern plant, sometimes several feet tall. On the underside of these big leaves (called fronds) form the sporangia where new spores are made. Remember that some ferns do not form the sporangia on the underside of the fern fronds (page 30).

In mosses, the thread-like plants that grow from spores become the green mossy plants that you see on wet stones, tree trunks, and decaying logs. The male and female structures form among the leafy parts of the moss plants. When an egg is fertilized, it grows into a tall spore-bearing portion with a capsule on top (see page 6). The hat that the capsule wears is all that is left of the stretched and torn female portion. Once it was urn-shaped and contained an egg. After the egg was fertilized, the fast-growing capsule on its slender stalk pushed the top of the urn right off and up into the air where it rests like a paper hat.

The thallus that comes from liverwort spores grows flat on logs, stones, and soil that are wet most of the year. You can sometimes see large

When they are white, shaggy mane mushrooms are good to eat. Later, they turn inky black and drip like the ones on page 10.

enough, they send up fruiting stalks where new spores are formed. In fungi such as mushrooms, the mycelium sends up an umbrella-like structure with gills or pores from which spores fall. Some species form shelf-like brackets on the sides of trees and spores fall from pores dotting the underside of these shelves. When you see a mushroom or a shelf fungus, remember that an extensive mycelium has threaded its way through much of the material on which the fungus grows.

The giant puffballs that spring up on warm, moist autumn nights are delicious to eat when sliced and fried. On the other hand, a few bites of some of the *Amanita* mushrooms can cause death. You can easily tell a puffball from other nonedible mushrooms, however, because the puffball does not have gills, it is not supported on a stalk, and it is ball-like in shape. Some of the giant puffballs may grow as large as a basketball and may weigh up to five pounds or more. If all the spores

Imbedded in this tiny tree-like reproductive structure are sacs filled with spores that will make more liverwort plants.

patches of liverworts in moist gorges, along creeks, and in wet woodsy places. Unlike mosses, few liverworts have pointed leaves. Instead, their flat thallus hugs the ground like a branching ribbon. A few liverworts that seem to have leaves resembling mosses have no midrib in the leaves, and their leaves lie flat instead of coming out all around the stem.

Occasionally an inch-high structure resembling a tiny tree grows from the thallus of some liverworts. The male and female parts containing eggs and sperms develop on these tiny trees. When an egg is fertilized, it forms a tiny capsule containing spores. You sometimes can see these capsules projecting from the underside of the tree-like structures like gleaming black pinheads. The spores they produce can grow into new thallus plants if they land where conditions of moisture and temperature are right.

The spores of fungi are even smaller, more numerous, and often simpler than those of the ferns and mosses. When spores of many kinds of fungi land, they germinate to form a tangle of whitish threads that grow all through their food material. You see, fungus plants cannot make their own food as mosses and ferns. They must get their food from slices of bread, jams and jellies, milk, tree trunks, leaves, fruits, or similar material. When the masses of threads called the *mycelium* (my-see'lee-um) have grown thick

You can actually write with the spore filled ink of an overripe shaggy mane (inky cap) mushroom.

school in dark, warm, and damp places. If you cannot find such a place, put an orange in a corner of your basement and leave it there for a week or so, or put some apple slices, a piece of slightly moistened bread or cake, and a piece of cheese in a plastic bag and put it in a drawer for a few days. See how many different colored molds or mildews you find when you remove it. Look at them under a magnifier and try to find any round sporangia on slender thread-like stalks. What other interesting molds or mildews can you grow?

BACTERIA — THE TINIEST PLANTS

Bacteria are smaller than the tiniest spores from any of the larger plants. They can be seen only with a powerful microscope, yet they are among the most important of the non-flowering plants. Some of these single-celled plants are so tiny that almost a thousand of them would fit side-by-side in the period at the end of this sentence.

Bacteria usually reproduce by splitting in two. They may do this as often as every 20 minutes when conditions of temperature, moisture and food are right. To see how many bacteria could develop in 24 hours from a bacterium that splits every 20 minutes, complete this exercise:

Time	*Number of Bacteria*
0 minutes	1
20 minutes	2
40 minutes	4
1 hour	8
1 hour, 20 minutes	16
1 hour, 40 minutes	32
2 hours	64
(Continue to 24 hours)	(Double the number each 20 minute period.)

Bacteria grow this fast for only a short time, however, because their food supply usually does not last for long, and their rate of reproduction decreases as their food dwindles. When their food supply is exhausted, they die or become dormant until more food is available.

Like all other living things, bacteria also give off waste products that are toxic (poisonous) to them. As their numbers increase, their waste increases until it slows their reproduction; it may stop them from reproducing at all, or even kill some of them. For these two reasons, the final figure on your sheet is rarely reached. You can see, however, how fast these microbes can grow when conditions are right for them.

Many persons think bacteria are harmful and should be avoided at all costs, but most bacteria are harmless. In fact, we would find life almost impossible without some of them. Like most other fungi, bacteria play an important role in breaking dead plants and animals into raw materials that can be used again by growing plants and animals. If it were not for these useful fungi, the

The giant puffball, white and edible, often grows larger than a football. It can produce billions of spores.

White puffballs are good to eat. Later the inside becomes a mass of brown spores.

from such a puffball germinated, and grew into puffballs, and their spores also grew into puffballs, the third generation would outweigh the earth 1000 times! Of course, few spores ever become mature puffballs.

A few flowerless plants form spores in less conspicuous structures than fern sori, moss capsules, mushrooms, or shelf fungi. Instead they form a few spores in thousands of tiny sacs. The mildews that you sometimes see on fruit or jams and jellies are examples. The slightest air currents moving across these mildews carry away thousands of spores that stick to dust particles, or just float around in the air. Plenty of these spores can fall and grow upon an old shoe, an apple or orange, or almost any organic material that is left in a warm, moist place.

Yeast is a very simple fungus plant that looks nothing like mushrooms and mildews. For the most part, yeast cells live alone. When they are fully grown, they may form bumps or buds at the side; when a bud is big enough, it breaks away from its parent and becomes a yeast cell by itself. Occasionally, however, yeast cells do make a few spores that can produce new plants.

Yeast that you buy at the store is a small cake of dried yeast cells that will begin to make more cells when they are mixed with sugar and water, or with bread dough. As they live and grow on the sugar or the starch, they make both carbon dioxide and alcohol. Just as you breathe out carbon dioxide, yeast cells also give off carbon dioxide. You also breathe out water vapor, but yeast cells give off alcohol. The alcohol that yeast cells make evaporates in bread that is baked, but in sweet cider that is allowed to stand, alcohol may accumulate until the cider is "hard." To keep it sweet, bottlers often add a chemical called benzoate of soda to slow the growth of yeast in the cider.

It is easy to find molds and mildews growing around your home or

The tiny white nodules on the root of this alfalfa plant contain bacteria that help convert nitrogen gas to a form the plant can use.

raw materials needed for growth would long ago have been used up and none would be available today.

Imagine what it would be like if all our garbage represented materials that could never be used by new plants. Think what our forests would be like if the earliest trees had removed permanently the materials necessary for growth. If this were true no seed could grow very long for lack of necessary minerals. Because they speed decay, bacteria and other fungi are as important as the green plants themselves, even though we seldom see these fungi at work.

Some helpful bacteria live in the roots of plants. You can see where such bacteria live if you examine clover or alfalfa roots. After digging up the plant, carefully wash the soil from the roots and look for lumps about pin-head size on the roots. In these lumps, or *nodules,* are bacteria that take nitrogen gas from the air in the soil, and put it into a chemical form that plants can use.

Other helpful bacteria make vinegar from hard cider, sauerkraut from cabbage, cheese from cream, and sour milk from sweet milk. Hemp can be made into rope only because bacteria decay the inner, soft part of the plant stems and leave the outer part in useful condition. Linen thread is made from flax in this same way. Bacteria also help in many other ways. Some of the books listed at the end of this Leaflet will give you more information about them.

Pneumonia, tuberculosis, diphtheria, typhoid fever, and spinal meningitis are among the diseases caused by bacterial infections. Because the bacteria causing these diseases are so tiny, they are easily carried on clothing, in water, or even by sneezing. Most of these harmful bacteria will be killed if they are exposed to the temperature of boiling water for several minutes. Most hospitals sterilize clothing, dishes, and instruments in huge pressure cookers called autoclaves where hot steam under high pressure kills *all* bacteria.

ALGAE: THE OLDEST GREEN PLANTS

Have you ever seen a greenish, paint-like coating on the bark of trees, on moist ground, on fence posts, or along the base of concrete or brick walls where rain water drips? This greenish coating, too thin and leafless to be moss, is algae (*al'jee*: singular, *al'ga*). The smallest of all green plants are algae, although some grow to be longer than an elm tree is high. Like fungi, mosses and ferns, algae have no flowers.

Because algae grow in water and are so small, they are often overlooked by young botanists. Actually they are among our most important plants because they are the smallest to make their own food. They serve as an aquatic pasture for countless tiny animals. These animals, in turn, feed other larger animals upon which we depend for food and other things. You will read more about this on page 17.

Some algae grow in fresh water; others grow in the sea. Examples of fresh water algae are pond scum or "frog spit," the green felt that clings to stones in a brook, and the green coating on the inside of aquaria that stand in sunlight. In the ocean, most algae are microscopic. They float in the open sea by the billions, but you can find much larger ones attached to rocks along the shore. Some algae can grow on snow; others grow in hot springs where almost no other organism can live. Some fresh-water algae grow on animals such as dragon fly nymphs and snapping turtles. Yellowish algae that live in the sea give the sulfur-bottomed whale its name.

The algae that grow on tree trunks and fence posts are some of the simplest forms. One of these, *Protococcus* (from *proto,* meaning first, and *coccus,* meaning seed, or little kernel), is a very simple alga that does not produce spores. It multiplies by simple division of the tiny round cells. Sometimes the cells stick together in clumps and sometimes they remain single. You may be able to see some of these round cells if you scrape a little of this algae from a tree trunk and put a tiny bit under a microscope. Estimate how many tiny rounded cells

This mass of filamentous green algae was found growing in the stream of a county park. It provides food and shelter for many tiny stream animals.

floating organisms are called *plankton*. Because algae are the smallest food-makers, the algae in the plankton are the beginning of many *food chains*.

A food chain is the story of who eats whom. Suppose, for example, that a small mayfly nymph living at the bottom of a stream eats a bit of algae from a stone growing in the water. The algae made its own food from sunlight and water. Once eaten, the food that it stored becomes part of the mayfly nymph. Later, the mayfly nymph is eaten by a small minnow called a darter. The darter is eaten by a brown trout, and the trout is finally caught and eaten by a fisherman. Although the fisherman thinks he is eating trout, in a sense he is really eating algae. Of course the fish is not green and plant-like, but without the algae in the stream, the fisherman could not have had a trout. The algae were the very beginning of the food chain that finally led to man.

Remember, however, that no food chain really stops with the largest animal. After the largest animals have eaten their prey and die, decay organisms such as bacteria and other fungi return them to raw materials that permit the food chain to begin again. The Leaflet for Spring, 1962, will tell you more about food chains.

The algae of ponds and streams are numerous in summer when the sun is high and the water is warm. In the fall and winter, many of them die. In some, only a hardy spore-like cell remains on the bottom of the pond or stream. When the water warms in the spring and the sun begins to climb in the sky, these special cells grow into new filaments that lengthen, break into smaller pieces, and continue to grow until they form a new mat of algae. In late summer when a pond has a great deal of algae growing in it, some people say the pond is "working." If an unpleasant odor is associated with the pond, it may be because some of the algae are dying and starting to decay.

In oceans as well as in fresh water, algae have ups and downs in their population growth. When the sun is high and the minerals necessary for growth plentiful, the phytoplankton (the plants such as diatoms in the plankton) increase at an enormous rate. In some parts of the sea during good growing conditions, the phytoplankton may total more than five tons per acre of ocean surface!

When the sun is low in the sky, or when most of the available minerals are tied up in living things, many of the phytoplankton die and slowly settle to the bottom of the sea where they decay. It may take several months for the minerals released by their decay to spread to the surface, and ocean currents may carry them hundreds of miles before they rise again. If the sun is high in the sky when minerals are plentiful again, up goes the population of these tiny plants. For millions of years this cycle has been repeated in the oceans.

you can see among the scrapings. Think how many there must be in the coating on a single tree!

Protococcus usually is more abundant on the north side of tree trunks or fenceposts because this side gets the least sunlight and therefore is more moist. People sometimes say that moss grows on the north side of tree trunks; what they usually mean is that algae grow on the north side, because green algae grow there more often than moss. When a tree is shaded by other trees to the south, the north side of its trunk may be drier than the south side. Then where would *Protococcus* be more abundant?

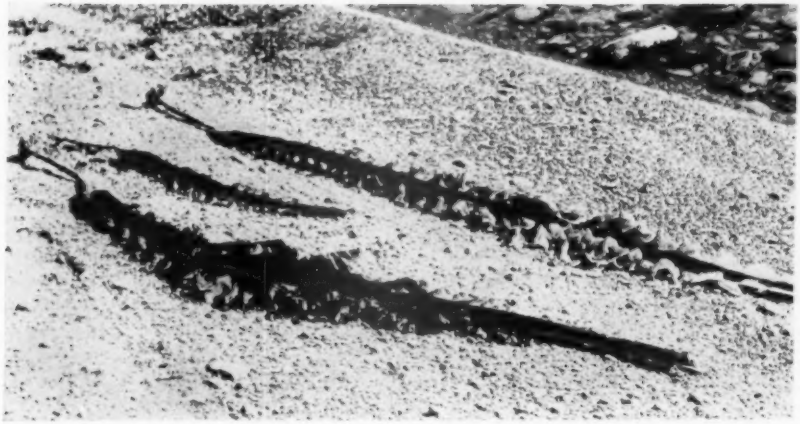
The green slime that coats sticks and stones in streams and ponds may be any of several kinds of green algae that grow in filaments or strings. Each filament may have dozens of cells, some to make food and others to help reproduce the plant. In some of the filamentous algae certain cells produce female parts and others produce male parts. A sperm and an egg combine to form a tough hardy cell that may spend the winter on the stream or pond bottom and start growth anew in the spring. At other times this cell may produce spores that scatter to make new plants. Algae reproduce in an amazing variety of ways.

When conditions of temperature and light are best, the filaments of fresh water algae form huge masses, with thousands of filaments tangled together. Here and there in these masses you can see bubbles. These are not ordinary bubbles: they are bubbles of nearly pure oxygen. These green algae carry on photosynthesis just as trees and grass do. The oxygen they make dissolves in the water where fish and other smaller creatures use it. When the water is warm and the sun is bright, the algae make food and oxygen so rapidly that bubbles of the gas collect faster than they dissolve.

In the ocean live billions upon billions of single-celled algae called *diatoms*, which look like microscopic Petri dishes because each has two glassy halves or valves that fit together. Inside each pair of valves is a single-celled plant that can make its own food. You cannot see these plants when you look at sea water from the deck of a boat, or even when you swim or wade in the ocean. If you put sea water through a very fine filter, however, you would be amazed at the variety and amount of plants and animals you had collected.

Diatoms are also found in fresh water. You can see these if you use a microscope to examine a bit of material scraped from a stone in a stream bottom or from the bottom of a shallow pond. Can you find any miniature glass shoe-boxes under the microscope? How many other interesting shapes of diatoms can you find?

Along with the diatoms in fresh water are many other small organisms. Some are other kinds of algae, and some are tiny animals that feed on the plants. These countless tiny



These kelps, one over five feet long, washed up on a Nova Scotia shore. Can you see the holdfast structures at the left?

Some kelps form great masses whose tips float at the surface, but whose holdfast structures are fastened to the ocean bottom many feet below. Often a group of animals will spend their lives in and near the beds. The sea otter, an animal the size of a large dog, often spends much of its life among the kelp beds, eating and sleeping as it floats on its back. It may wrap strands of kelp around itself to keep from drifting away while it dozes. One kelp bed may serve several sea otters as a sort of "kelp dormitory."

In addition to providing protection and food for sea animals, algae are an increasingly important food source for people. On the east coast, a marine alga called Irish moss is harvested for its gelatin which is used in instant whips, mayonnaise, toothpaste, and a number of other products. Chocolate milk would not be so smooth and creamy without an extract from marine algae that helps keep the chocolate suspended in the milk.

On the west coast, kelps are harvested and used for many of the same purposes as Irish moss. Once a modest industry, the harvesting of marine algae is now a multi-million dollar business in the United States.

In addition to providing food for people on earth, some algae are being studied as possible food for space travelers. *Chlorella,* a genus of freshwater algae, is one of these. Perhaps one day you will eat a tasty meal on a space ship as a result of experiments with algae — the oldest and the simplest of the flowerless food makers.

Most of the flowerless plants in the ocean are microscopic and live far from land. Some, however, are large and grow along the coastline. If you take a walk along a rocky east coast seashore, you may see mats of coarse algae called rockweed covering rocks that are exposed at low tide. Many of the algae that grow in the intertidal zone (between the high and low tide marks) have small air bladders scattered among their foliage. These bladders help to keep the algae near the surface where there is plenty of light for photosynthesis. If you step on them, you can hear the air bladders pop.

Almost all large marine algae have some means of holding fast to the rocks or debris on which they grow. If they did not cling tightly to the bottom, the waves and currents would soon detach them and wash them up on the shore to decay. Along an ocean beach, you sometimes can find a large marine alga such as the kelp shown on page 19 which has been washed ashore. Unless it has been broken, you can see the large flattened leafy portion, a long stalk, and the holdfast that attaches the alga to the ocean bottom. Some kelps grow to a length of 200 feet or more!

The rocks along this Maine coast are bathed in salt spray from the waves. On them grow mats of marine algae called rockweed or Fucus.

These pixie cup lichens, growing in a clump of moist moss, are examples of symbiosis. They represent both an alga and a fungus growing together.

animals. In the tundra country of the North, animals such as reindeer and caribou depend upon reindeer moss, a kind of lichen, for their winter food. They use their hooves to scrape away the snow and ice covering the mats of lichens.

Lichens are used for food by some people, too. The biblical account of the Israelites and the manna probably is based on lichens that washed down from the mountains in hard showers. Even today some nomads of the Middle East grind lichens to make flour.

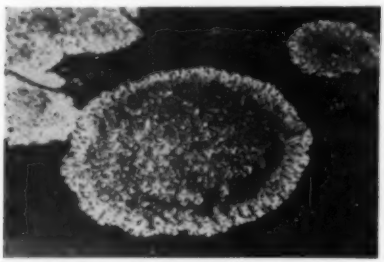
Lichens may grow on other planets, too. The planet Mars has polar ice caps that grow and recede with the change in seasons. As the ice cap of one hemisphere recedes, the markings in that hemisphere become darker and take on a greenish hue. Some scientists have suggested that this greenish color is caused by vegetation such as the lichens of our earth. The possibility of finding plants like ours on another planet is exciting, and is one of the big questions to be answered by the first earth visitor to Mars.

Lichens are of some importance to the chemist as well as to the botanist. Litmus paper is treated with juice from a lichen that is color sensitive

LICHENS: PLANT PARTNERSHIP

Algae normally need a large amount of moisture to grow; often they will grow only when they are covered with water. Some algae, however, can grow where it is quite dry if another plant grows with them to keep them from drying out completely. Lichens, for example, are a fungus growing right along with an alga. The two are so mixed that cells of the alga grow right in with the mycelium of the fungus. Although a lichen may have a scientific name, it is really *two* plants growing together.

The alga is the food-maker of the lichen and the fungus the water-supplier. Because the fungus cannot make its own food, the alga feeds the fungus and the fungus protects the alga. This adventure in togetherness is known as *symbiosis.* The lichens are one of the best known examples of symbiosis. Can you find others?



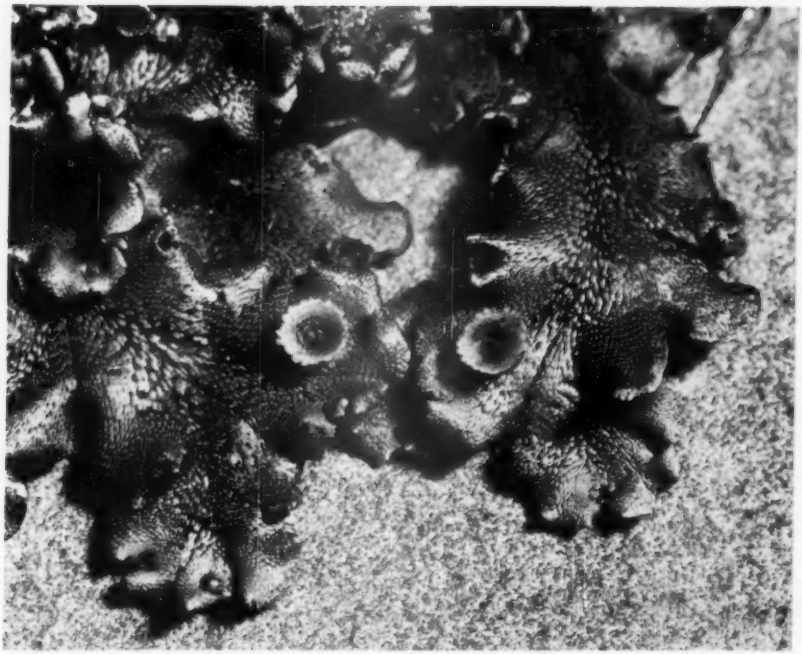
Parmelia, the common rock lichen often grows in round patches. Like all other lichens, it combines a fungus and an alga.

One common genus of lichen is *Parmelia.* These grow in greenish-gray patches on rocks and on tree trunks. There are several kinds of *Parmelia,* but one of the most abundant is shown below. Can you find any like it around your home? Because lichens grow slowly, stones or rocks must be undisturbed for a long time to show them. If you see a stone with a large lichen growing on it, you may be fairly certain it has been in place a long time.

Chemicals from the plant fibers, and the swelling and shrinking of the fibers as the plants repeatedly absorb water and then dry out, slowly erode the surfaces of the rocks on which lichens grow. Gradually the bits of eroded rock and decayed plant material form soil. Of course, it takes hundreds of years for much soil to form, but plants have lots of time; it is only man who is impatient.

When lichens have succeeded in forming a pocket of soil that will retain moisture, mosses may begin growing. As more and more rock is eroded and mixed with decayed plants to form more soil, ferns and small seed plants can begin to grow. Thus, as small and slow-growing as they are, the lowly lichens may be the first stage in a progression of plants that eventually includes the tallest tree.

Lichens are not only important as soil builders but as food for many



In these tiny gemmae cups of Marchantia are still tinier clumps of cells that can make new liverwort plants.

structure are the male and female parts. When the egg cells are fertilized, they form spore cases from which the spores tumble to form new plants.

Occasionally tiny cups form on the upper surface of the thallus of some liverworts. You can see these in the photograph above. In these cups are tiny seed-like structures, or gemmae (jem'me). Under a magnifier they resemble green eggs in a miniature bird nest. The gemmae are groups of cells that can scatter to make new plants. They are not spores, and are not formed by male and female parts; they are just groups of cells of the thallus.

When you walk through a shady gorge, or where a brook cuts through a rocky ledge, look for liverworts. If you find one that has the appearance of a green snake skin with prominent cell-like divisions on its surface, it is probably *Conocephalum*. Can you find a pore (stoma) in the center of each section, where gases enter and

to changes in acidity; the lichen extract turns blue when an alkali is added to it, and red when an acid is added: You can test litmus paper for yourself on such household chemicals as lemon juice, vinegar, ammonia water, sour milk, and milk of magnesia. Which turn the litmus paper blue? Which turn it red?

Even though lichens are important as soil builders, as food, and for their chemicals, they are also important just for their beauty. The genus *Cladonia* has several very interesting forms. One form, called British soldiers, grows on old logs, tree stumps, and stone walls. It is almost as slender as a pencil lead, about an inch or so in height, and grayish-green with brilliant red tips.

Another *Cladonia,* known as the pixie cup lichen, resembles a tiny cup or wine glass. It grows to a height of an inch or so. Sometimes certain species of Cladonia will grow cup upon cup until a three- or four-story stack of cups results. Watch for these tiny but fascinating structures when you are roaming woodland borders or old fields.

LIVERWORTS

Liverworts are simple plants that resemble lichens, but cannot grow just anywhere as lichens do. They must grow where it is very moist. They are more advanced than algae, however, and represent a step toward the establishment of true land plants.

Liverworts get their name from the fact that some people thought the plants were liver shaped. In olden days some people thought that eating liverworts would cure diseases of the liver. Of course, this is not true.

Many kinds of liverworts grow in New York State, but two are so different from other small green plants that you can recognize them easily. They are *Marchantia* (marcan'che-a) and *Conocephalum* (cone-o-seh'fa-lum). On page 23 is a picture of *Marchantia* growing between the stones of a terrace. More often, these two plants grow where water drips on rocks, on a wet log, or in the soil near a waterfall or a spring. Because they need plenty of moisture, do not look for them in dry places.

A few liverworts are leafy like mosses, but you are more likely to recognize the ones that resemble forked green ribbons growing flat on the ground. They have no roots; instead, a fuzzy growth of hairs on the underside helps them cling to the surface. Because they have no tubes to carry water and food to their parts, they cannot grow tall like ferns or weeds. They are just flat, leafy green plants that hug the ground.

Liverworts have an interesting method of reproduction. A tiny tree-shaped structure grows from the upper surface of some species. On the underside of the branches of this

plants. A few mosses resemble trees because they have a single trunk-like stem with numerous branches arising from a point an inch or two above the ground. To a casual observer, these uncommon tree mosses might be mistaken for the larger, coarser club mosses that are not mosses at all, but are related to the ferns.

As you learned on page 9, most mosses begin their growth from a spore. When the spore germinates, a green thread grows out, enlarges, and soon grows into a moss plant. From the tips of the mature, leafy moss plants grow male or female structures. In the female part the spore-bearing structure (the sporophyte) forms, and grows upwards to end in a capsule filled with spores. In many species both the moss plant and its sporophyte can be seen at most times of the year.

Although they do not have the commercial importance of some other flowerless plants, mosses are still important for several reasons. They are an important step in the formation of soil from exposed rocky surfaces. As with lichens, it may take mosses centuries to build enough soil to enable some of the larger plants to germinate and grow to maturity. At the same time they help to decompose rock, they retain considerable moisture along with the bits of rock that are loosened by erosion from plants and weather. Without this protective cover of moss, the loosened rock might be washed away as fast as it eroded.

Mosses such as *Sphagnum* are important soil builders in bogs. The bogs in which Sphagnum moss grows are quite acid. This high acidity slows bacterial growth, and in turn slows decay. The parts of moss plants that die settle to the bottom of the bog and remain almost undecayed for years. As they accumulate and become packed together, they form a brown, punky mass called peat. In Ireland, and in many parts of North America, peat is removed in chunks, dried, and used as a fuel that gives off about half the heat of the best soft coal.

Peat is also used for garden mulch. In New York State there are several bogs from which peat moss is removed, dried, baled, and sold in garden stores. People work it into the soil around foundation plantings to help hold moisture.

During World War I, dry sphagnum moss was used for surgical dressings. Its ability to absorb up to 20 times its own weight made it better than cotton because it did not need to be changed so often. Antibiotic preparations are now used with the cheaper cotton gauze, and sphagnum dressings are no longer used.

Nurserymen pack sphagnum moss around the roots of transplants and new cuttings. They grow some new plants by cutting off a branch, putting a hormone on the cut to stimulate root formation, and covering the cut end with wet sphagnum moss. They also pack wet sphagnum

leave? Can you find any gemmae cups? If you are lucky, you may find the little tree-like structures that hold the reproductive organs. Can you find any shiny black spore capsules under the top of the tree-like structures?

If you find liverworts, take up a small piece of one and put it in a terrarium. Keep the terrarium out of direct sunlight so your liverwort will stay healthy. Then you can have an example of one of the earliest plants to live successfully on land.

MOSSES

Credit must go to the lichens for being the first plants to gain a foothold on bare rock, even when it is exposed to the raw, frigid climate above timberline. Not long after the lichens are established, however, moss spores find enough moisture to germinate and establish this second group of hardy plants. Their leaves will shrivel under scorching sun, but come back again green and soft with the first rain. They can withstand searing summer heat and wintry blasts, and can grow where trees cannot. Together with lichens, they make up the predominant vegetation on exposed mountaintops and other places where bigger plants cannot survive.

In a favorable climate, mosses grow in lush green mats. They may cover rocks to a depth of several inches when conditions are right. When this happens, there is no cover of plants that gives quite the same impression of soft greenery. To a weary hiker on a hot summer day, nothing offers such a deliciously restful bed as a carpet of moss.

Mosses have small leaves and short stems because there is no network of conducting tubes to carry water and minerals from one part of the plant to another. For this reason, mosses can never grow tall, no matter how good the growing conditions. They are limited to life at the soil surface, near their supply of water and minerals.

Some mosses grow in clumps; one, called the pincushion moss, is bright green and looks like a natural pincushion dropped here and there along woodland borders. Some rarely form a cushiony mass, but grow as a thin carpet over moist rocks along stream borders. A few grow right in the water where a waterfall cascades over them constantly. Most grow on the soil, or on rotting logs or stumps where a good supply of moisture and a solid surface are assured.

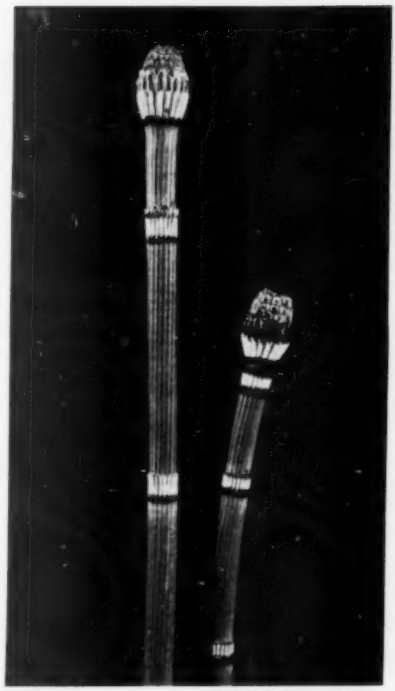
Most mosses consist of unbranched, leafy stems rising from the ground. Haircap moss, pincushion moss, *Minium,* and even *Sphagnum* mosses are of this type. Others such as the fern mosses have branching stems that resemble miniature fern fronds. These beautiful mosses make excellent terrarium

food-making frond come green branches that resemble long, light green pine needles. In fact, the field horsetail of summer looks like a miniature evergreen tree. It spreads a soft green over waste places, but even more important, it helps to hold the soil in these places where most other plants cannot grow. With the first hard frosts of autumn these delicate green plants die down, and their underground stems remain dormant until they send up the fertile fronds again in spring.

Unlike the pale, fertile fronds of horsetails, the fertile fronds of scouring rushes are green and make their own food. They have only one kind of frond — a tall, dark green, slender but stiff stalk with a strobilus at the top. They have the same little sheaths around the nodes that the horsetails have. In addition, their green stems are often finely grooved lengthwise.

In the outer covering of the scouring rush is *silica,* the mineral that makes sand, and gives the scouring rush its name. In bygone days, people used scouring rushes to scrub their pots and pans, or to give a high polish to wood surfaces. Of course, they have long since been replaced by cheap commercial sandpapers and scouring powders.

If there are horsetails or scouring rushes growing near your home or school, look for the spore-bearing strobili at their tips. Dig up a section of a root-stock and see if you can find the buds that will produce next year's fronds. Can you find both fertile and sterile buds on a single rootstock of field horsetail? If you can find scouring rushes (remember that they are unbranched, green, taller and stiffer than the horsetails), dry some and try scouring a metal pan with them. Can you feel the gritty material in their stems? Remember that these plants have a history far longer than that of man, or elm trees, or roses.



These scouring rushes do not die in winter as most other horsetails do. The silica in their stems keeps them stiff. Spores form in the strobili at the top.

around newly potted plants and around the cut ends of flowers to keep them fresh.

Despite their commercial value, mosses are probably more important for their beauty and their ability to grow where other plants cannot. They help to hold soil in places where rain and snow might wash it away. They form a mat where other seeds eventually can germinate, take root and grow. They also provide some of the most beautiful ground cover in nature. When you look at the mosses underfoot, observe how these hardy little plants can withstand the most rigorous blasts of winter and the most torrid days of summer, yet come back green and lush with the first warm rains. They are delicate, yet hardy; humble, yet prodigious.

THE HORSETAILS OR SCOURING RUSHES

Early in the spring, along railroad embankments and sandy, waste places you often see pencil-sized, flesh-colored stems arising from the soil. At the tip of each is a miniature brown cone about an inch long. This is the fertile shoot of the horsetail, a miniature survivor of the huge plants that lived and died during the Carboniferous Age. These early relatives of the horsetails formed many of our coal deposits.

The horsetails or scouring rushes look different from other green flowerless plants. They have jointed stems and each joint is wrapped in a tiny sheath. They give the appearance of having grown in a telescoping fashion, as you might pull out the leg of a camera tripod or a telescoping radio antennae or fishpole. The stem really does not telescope, but grows longer between each of these little collars or sheaths. Look at these sheaths with a hand magnifier. Can you see a ring of teeth that hides the base of the section above?

The pale fertile shoots that come up early in the spring produce and spread spores. The spores tumble out of the strobilus (strow'bi-lus) or cone-shaped portion at the top. Each spore is equipped with slender arms that twist and turn as they dry out, but remain tightly wrapped about the spore when it is wet. Like the spores of mosses and ferns, horsetail spores scatter best when the air is dry. Collect some of these spores in the spring and put them under a microscope. What happens to the arms when you breathe on them?

After the fertile portion has done its work of spreading the spores, it dies back to the ground and a delicate green, food-making frond comes up. These sterile fronds or shoots remain green all summer. Their stems are more fragile than those of the fruiting portion, but show the same jointed appearance. The little toothed sheaths that surround each node (joint) are even finer and less conspicuous than in the fertile stems.

From each of the nodes of the

us best by anchoring the soil on exposed, poor sites, and by forming attractive, evergreen covers in upland woods and fields. When you find them, trace the long, running stem to its beginning. Look at the spore-bearing cone at the tip of the upright stems. In some kinds you may find that there is no single cone, but that each green leaf near the tip has a spore case at its base. Some of the references at the end of this Leaflet will tell you other interesting things to look for in club mosses.

FERNS: LARGEST UPRIGHT FLOWERLESS PLANTS

Of all flowerless plants, ferns have the most highly developed vascular (conducting) tissue, and grow tallest. In rich, moist soil the ostrich fern may grow to a height of five feet or more. Bracken fern, a three-leaved fern that grows quickly where woods have been opened up by fire or by cutting, will grow nearly shoulder high under good conditions. A few ferns such as the spleenworts, however, may be only a few inches tall.

It is true that some primitive non-flowering plants such as the kelps grow to great lengths, but these large algae absorb their nutrients directly from the water in which they grow. Ferns, on the other hand have true roots to absorb water and minerals from the soil, and vascular tissues to conduct these materials to the leaves where the food is manufactured.

The leaves or fronds of ferns show great variety in size and shape. Most fronds are divided into smaller sections called pinnae which you can see on the cover. Sometimes these pinnae are divided into still smaller sections called pinnules.

The rare walking fern has an undivided leaf that is long and tapering. The leaf has a habit of taking root at its tip, and this habit gives the plant its name.

Another fern does not resemble a fern at all; it looks like a large four-leaf clover and it grows in the water. It is called a water fern or water shamrock. You often can see these in ponds and quiet bays where the water is warm and shallow, and can find its bean-like spore cases growing from the rootstocks in the pond bottom.

The leaves of most ferns are green, but they vary in shade from the dark Christmas ferns and holly ferns to the light green of bracken ferns. The stems show much more color variation; not all are green. The stem of the lovely maidenhair fern, for example, is a shiny purplish black. That of the cinnamon fern is covered with a reddish-brown wool that gives the fern its name.

Fern spores are produced in a number of ways. Most ferns bear their spores in fruiting dots on the underside of the leaves. Turn over the leaves or fronds of several ferns

CLUB MOSSES

Ground pine is a common name for the large, coarse club mosses. They grow much larger than true mosses because a system of tubes has developed in them to conduct water and other materials to and from their roots and branches. Some of the club mosses such as the tree club moss shown below may grow to heights of a foot or more. Others, such as shining club moss run along the ground, sending up stems that are only a few inches high.

Like other non-flowering plants, club mosses are not commercially important today. At one time they were used in a number of interesting ways, however. The spores of club mosses, which are produced in profusion as the picture on page 8 shows, were used in coating pills, in soothing wounds, and even in photographic flash powders because they ignite with an almost explosive flash when a mass of them is blown into the air and sparked. Lycopodium dust is a name given to these spores of club mosses, of which the genus *Lycopodium* is one of the most common.

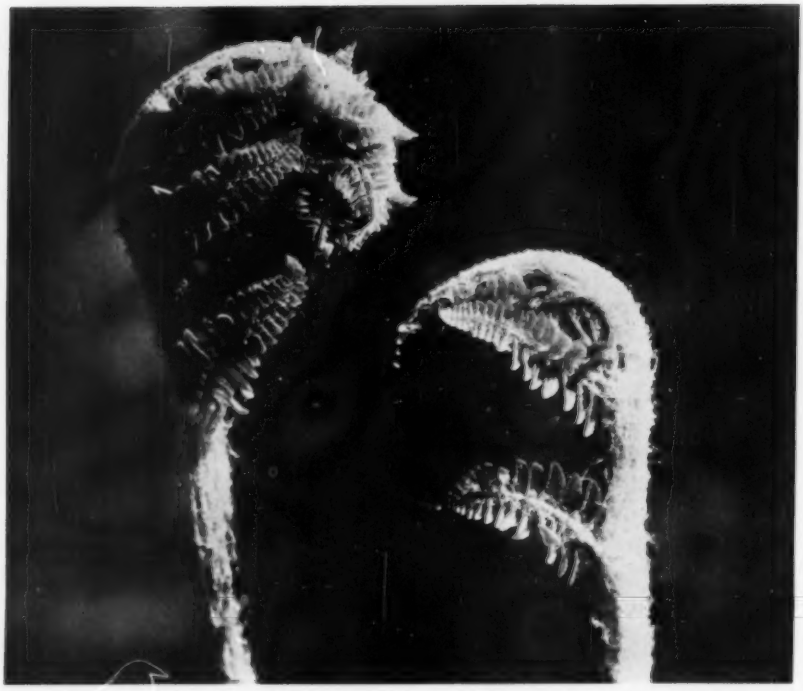
The spores of this club moss are formed in the strobili (cone-like structures) at the top of the plant.

Club mosses also have been used for Christmas wreaths because they have long, trailing evergreen stems. This practice should be discouraged, however, because most club mosses are not common enough to be pulled up in quantity. They also grow slowly, and it may be years and years before a patch of club moss that is removed is reestablished.

As with the horsetails, club mosses are remainders of an ancient group of plants that formed vast green jungles over much of North America. These giant club mosses, along with horsetail trees and giant ferns, are now coal deposits in Pennsylvania, West Virginia, Illinois, Alaska and several other states.

Little is known about the germination of the spores of the club mosses. They may take several years to grow into young plants, and perhaps ten years more to develop the spore-bearing portions. A mature club moss that is producing spores may be many years older than you.

Although they once had limited commercial value, club mosses serve



The uncurling fiddle-heads of the cinnamon fern show in miniature the leaves that later become large and spreading.

and see if you can find the fruiting dots or sori (page 7) near the tip of the leaf. In some ferns such as the wood fern, the sori are dots scattered under each pinnule. In the maidenhair fern the sori are formed by rolling under of the leaf margin. In the sensitive fern, the sori are formed by a whole leaf rolled up. The interrupted fern has fertile pinnae midway up the fern leaf. It gets its name because these fertile pinnae become wrinkled and brown while the rest of the leaf remains green.

Most ferns die back to the ground each fall when cold weather comes. A few such as the Christmas fern and the polypody fern that grows on big rocks in woods remain green all winter. Even though most ferns die back, their tough, perennial rootstock lives and grows. In the spring, new fern leaves push up from the ground in the form of a fiddlehead. Then they uncurl to form new fern

leaves. On page 30 is one of these fiddleheads of the cinnamon fern emerging from the swamp in which it grew. Some fern fiddleheads, especially of the bracken fern, are considered good eating if collected in the spring when they are tender.

Like so many other flowerless green plants, the importance of ferns does not lie in their commercial value. Instead, ferns are important mostly for their contribution to the landscape — as shelter for smaller plants, as holders of soil and moisture, as cover for animals, and as a bit of woodland greenery that fills in between the moss and the trees.

SOME HELPFUL REFERENCES

For the Teacher:

COBB, BOUGHTON, A FIELD GUIDE TO THE FERNS, *Houghton Mifflin, Boston, 1956. 273 pages.* A field guide for the beginner, illustrated with excellent black and white sketches. In the back of the book are sections on horsetails and club mosses.

CONRAD, HENRY S., HOW TO KNOW THE MOSSES AND LIVERWORTS, *Wm. C. Brown, Dubuque, Iowa, 1956. 226 pages.* A semi-technical key to mosses and liverworts for those who wish to go much further than the average teacher.

GROUT, A. J., MOSSES WITH A HAND LENS, *published by the author, Newfane, Vermont, 1947. (Out of print.)* A semi-technical book, available from many libraries, is still the most complete book on mosses for the amateur. Primarily for identification, with the back section devoted to liverworts.

KRIEGER, LOUIS C. C., THE MUSHROOM HANDBOOK, *Macmillan, New York, 1935. (Out of print.)* One of the best small guides to mushrooms of eastern United States, still available from many municipal and school libraries. Contains a complete key, numerous descriptions, and color plates of common fungi.

PARSONS, FRANCES T., HOW TO KNOW THE FERNS, *Dover, New York, 1961. 215 pages.* A paper-backed descriptive field guide to the ferns of North America, especially of the Northeastern states. Good pen-and-ink sketches, supported by an interesting and non-technical text.

SMITH, ALEXANDER H., THE MUSHROOM HUNTER'S FIELD GUIDE, *University of Michigan Press, Ann Arbor, 1958. 197 pages.* An excellent pictorial and descriptive account of more than a hundred edible and poisonous mushrooms. Also contains several useful, non-technical keys, as well as lists of special habitats of mushrooms.

THOMAS, WILLIAM S., FIELD BOOK OF COMMON MUSHROOMS, *Putnam's New York, 1948. 356 pages.* A complete, non-technical field book, with black and white and some color plates. Contains a chapter on mushrooms other than those with gills, one on foods and recipes, and several keys.

For the Pupil:

GRANT, MADELEINE P., WONDER WORLD OF MICROBES, *McGraw-Hill, New York, 1956. 157 pages.* An interesting story of the history, use, and problems related to molds, yeast, and bacteria, and how man has successfully worked with them. Intermediate and upper.

SCHATZ, ALBERT AND RIEDMAN, SARAH, THE STORY OF MICROBES, *Harper, New York, 1952. 167 pages.* A rather comprehensive account of the size, classification, reproduction, history, and importance of microbes. Includes methods of culturing microbes, and their relationship to each other and to other living things. Upper.

SELSAM, MILLICENT, MICROBES AT WORK, *Morrow, New York, 1953. 95 pages.* A delightful approach to molds, yeasts, and bacteria that are frequently encountered around home and school. A number of easy, effective experiments and activities make this book a must for elementary classes. Intermediate, upper.

STERLING, DOROTHY, THE STORY OF MOSSES, FERNS, AND MUSHROOMS, *Doubleday, Garden City, New York, 1955. 155 pages.* Beautiful photographs supporting an interesting text that describes the forms of fungi, the delicate leaves and spore cases of mosses, and the lovely greenery of ferns. Includes a few descriptions of common species, as well as the evolution of these flowerless plants. Intermediate, upper.